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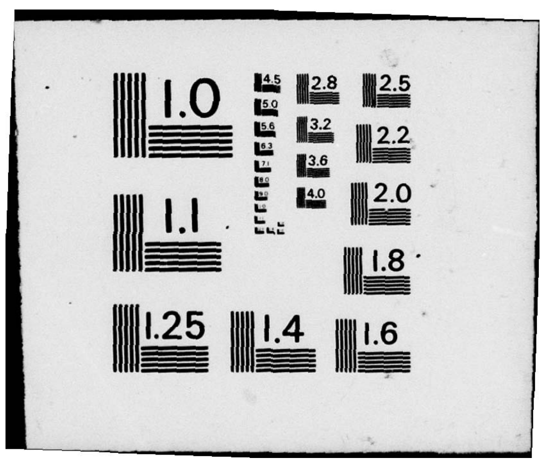
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AN EVALUATION OF CARGO AIRCRAFT FOR ANTARCTIC FIELD PARTY SUPPORT OPERATIONS

Paul J. Williams
CACI, Inc. - Federal
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The Division of Polar Programs of the National Science Foundation needs a small aircraft to support field party operations. A world-wide survey narrowed the field to five candidate aircraft: DeHavilland Twin Otter, Short Skyvan and SD3-30, IAI Arava, and CASA Aviocar. No aircraft met all "mandatory" and all "desirable" requirements, but the Twin Otter met all mandatories and was only aircraft with proven ski landing configuration. It was recommended for procurement.

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SUMMARY

The Division of Polar Programs of the National Science Foundation needs a small aircraft to support field party operations. Although a leased Twin Otter is currently used, it is planned eventually to procure two or three aircraft. Consequently, an analysis of candidate aircraft has been required to determine the aircraft best suited for this mission. Several performance and features requirements were specified. (See Section on Mission Requirements.)

A world-wide survey of commercially available aircraft narrowed the field to five reasonable candidates: the DeHavilland Twin Otter, the Short Skyvan, the I.A.I. Arava, the C.A.S.A. Aviocar, and the Short SD 3-30. No American-made aircraft in this size range met the mandatory high-wing configuration requirement. (See Section on Selection of Candidate Aircraft.)

The set of features and capabilities specified by the Division of Polar Programs was partitioned into the two categories: "Mandatory" and "Desirable." Table 1 illustrates that no aircraft met all requirements. The DeHavilland Twin Otter met all mandatories, however, and was the only candidate aircraft to do so. Further, the Twin Otter was the only aircraft with a proven ski landing configuration.

The Skyvan, Arava, and Aviocar have straight-in loading capability, while the Twin Otter and SD 3-30 do not. However, a simple, manually operable loading system, discussed in the Section entitled Features Comparison, appears capable of alleviating loading problems which have been experienced with the Twin Otter.

The principal cost factor is the procurement of the aircraft and spares. Costs of the SD 3-30 are substantially greater than three of the other candidates, whose acquisition costs are on the same order of magnitude*. Acquisition costs of the Aviocar are unknown. (See page 35.)

*Equipping any candidate aircraft but the Twin Otter with skis would introduce an element of development cost, emphasizing the Twin Otter's cost advantage.

TABLE 1. SUMMARY AIRCRAFT COMPARISON

	Twin Otter	Skyvan	Arava	Aviocar	SD 3-30
Mandatories					
Range/Payload	X	-	-	-	X
Ferry Range	X	X	-	X	X
Single-Engine Cap.	X	X	X	X	X
High Wing	X	X	X	X	X
Twin Turbine	X	X	X	X	X
Skis	X	-	-	-	-
Maintainability	X	X	X	X	?
Desirables					
Range/Payload	-	-	-	-	X
Ferry Range	X	(X)*	-	-	X
Single-Engine Cap.	X	-	X	X	X
Straight-in Loading	-	X	X	X	-
Equipment Commonality	X	-	-	-	-

*Unable to meet 2,000-mile range desired with auxiliary fuel tanks, but does meet 1,000-mile range required with internal fuel.

Since initial indications make the Twin Otter the preferred aircraft, and since the Division of Polar Programs is familiar with that aircraft, no user's comments were sought in reference to the Twin Otter.

The Twin Otter is the only aircraft that meets all of the mandatory requirements, and is deficient in only two of the desirable requirements (6600 pound payload at a 200 nautical mile range, and straight-in cargo loading). All other aircraft were deficient in certain mandatory requirements. (See Table 1.) Therefore, it is recommended that the Division of Polar Programs procure the Twin Otter.

MISSION REQUIREMENTS

The Division of Polar Programs of the National Science Foundation has been conducting a continuing Antarctic research program. One aspect of this program has been the collection of data from each node in a fifty kilometer grid superimposed on the Ross Ice Shelf.

The field parties that collect these data must be transported from base camps to the test site each morning, and must be returned to the base camps each evening. As the distance from a base camp to a test site is often greater than fifty miles, air transportation is necessary.

The Division of Polar Programs currently uses a Navy C-130 for major movements, such as carrying large numbers of persons, or large quantities of supplies, from McMurdo to the base camps. A UH-1N helicopter is used for certain short range, light payload field party support activities in areas with visual flight references. An intermediate aircraft, however, is required to support the field parties, particularly in areas such as the Ross Ice Shelf. Typically, this aircraft would carry several men and their equipment, including a mechanized toboggan weighing approximately 450 pounds. An alternate load might consist of several fifty-five gallon drums of fuel oil.

A DeHavilland DHC-6 Twin Otter is currently leased for this purpose. As the Division of Polar Programs is considering procuring two or three aircraft, rather than continuing to lease the Twin Otter, and since a number of different aircraft (including the Twin Otter) are to be evaluated, a set of specifications has been formulated. These specifications include performance and features.

PERFORMANCE

1. Maximum payload:

   4400 pounds mandatory
   6000 pounds desirable

   NOTE: Some flexibility is possible here, because the payload consists of a number of relatively light items. As distances are relatively short, *two trips* would be considered.

2. Range at maximum payload:

100 nautical miles mandatory
200 nautical miles desirable.

3. Range with maximum integral fuel:

700 nautical miles mandatory
1000 nautical miles desirable

4. Ferry range with auxiliary inboard fuel tanks:

1000 nautical miles mandatory
2200 nautical miles desirable

NOTE: All range specifications assume a fuel reserve sufficient for forty-five minutes holding, at the speed for best economy. No reserves for diversion, or provisions for headwinds, are considered.

5. Single engine operation:

Ability to maintain a rate of climb of fifty feet per minute, with one engine inoperative, at all altitudes up to 10,000 feet, at temperatures of I.S.A.[1] - 10°C, with at least eighty percent of full payload, is mandatory. Identical performance, at temperatures of I.S.A. + 0°C with full payload, is desirable.

CONFIGURATION AND FEATURES

1. Engines:

Twin turbine propulsion is mandatory. Either turbo-props or jets would be satisfactory.

2. Wing location:

A high wing configuration is mandatory. This is to avoid damage which would result from wing contact with the surface when operating on rough ice and snow surfaces.

3. Skis:

A dual (wheel and ski) main and nose landing gear is mandatory. High flotation, low pressure wheels are, by themselves, not sufficient. Furthermore, easy field installation and removal of skis is desirable.

---

[1] International Standard Altitude.

4. Cargo loading arrangement:

A straight-in cargo loading arrangement is highly desirable, with the door forming a shallow angle loading ramp.

5. Maintainability:

The quality of rugged construction, minimal failure rate, and simple inspection and maintenance, under rather primitive conditions, is mandatory.

6. Commonality:

Commonality of engines and airframes with other users of aircraft in the Antarctic is desirable.

SELECTION OF CANDIDATE AIRCRAFT

All aircraft listed in the 1976 Jane's All the World's Aircraft were studied to select a list of candidate aircraft which, prior to rigorous analysis, were believed to meet all of the required specifications listed in Section entitled Mission Requirements. An implied restriction was that the aircraft not be too large, as this would be an unnecessary procurement and maintenance requirement. Furthermore, the C-130 is available for the big jobs. Therefore, no aircraft with a design maximum take-off gross weight of 25,000 pounds or greater was considered. This was a reasonable, but arbitrary, limit.

Five aircraft were identified as being suitable candidates for further analysis. These were:

1. The DeHavilland DHC-6 Twin Otter (Canadian)
2. The Short SC-7, Series 3 Skyvan (British)
3. The Israeli Aircraft Industries I.A.I. 101 Arava
4. The Construcciones Aeronauticas, S.A. (C.A.S.A.) C-212 Aviocar (Spanish)
5. The Short SD 3-30 (British)

Summary weights, performance, and configuration data of these aircraft are presented in Table 2. More detailed information, such as tabulation of the roster of military users, certification status, and sources of information are presented in the Appendices.

None of these aircraft is American. Anticipating a preference for an American aircraft, a survey was made to determine the reasons why no American aircraft met the requirements. Essentially all American aircraft in the appropriate weight category were designed as passenger aircraft, and have a low wing. On the other hand, the American aircraft designed as freighters, with a high wing and easy cargo loading, are far too large for this requirement. Furthermore, the common use of certain of these candidate aircraft in this country is indicative of the lack of any high-wing domestic equivalent. The

TABLE 2. BASIC AIRCRAFT CHARACTERISTICS

	Twin Otter	Skyvan	Arava	Aviocar	SD 3-30
Max. T.O.G.W.	12,500	13,700/12,500	15,000/12,500	13,889/12,500	22,000
Wt. Empty, Equipped	6,462	7,600	8,300	8,250	12,400
Operating Wt.	7,000	8,050	8,800	8,750	12,900
Useful Load	5,500	5,650/ 4,450	6,200/ 3,700	5,139/ 3,750	9,100
Max. Payload	5,400	4,150	5,150	4,410	7,500
Max. Fuel (lbs.)	2,457	2,300	2,350	3,700	3,840
Range (integral tanks) (n.mi.)	960	985	630	1,140	1,025
Range (aux. tanks) (n.mi.)	2,406	1,844	1,247	1,339	2,947
Cargo Door Location	Left	Rear	Rear	Rear	Left
Cargo Door Size	4'-8" x 4'-2"	6'-6" x 6'-5"	4'-7" x 6'-7"	5'-7" x 13'-1½"	5'-6" x 4'-8"
Cabin Length	18'-6"	18'-7"	12'-8"	16'-5"	31'-1"
Cabin Width	4'-8"	6'-6"	6'-1"	6'-6½"	6'-6"
Cabin Height	4'-9"	6'-6"	5'-9"	5'-7"	6'-6"
V_{max} (10,000', max. G.W.) (knots)	182	169	172	194	195
Engine	PT6A-27	TPE331-201	PT6A-34	TPE331-S-2510	PT6A-45
E.S.H.P.	652	715	750	776	1,120
First Flight	5/20/65	1/17/63	11/27/69	3/26/71	8/22/74
Cost	$665,000 (no avionics) (Can. $)	$675,000 (no avionics)	$875,000 (with avionics)	unknown	$1,100,000 (no avionics)

Twin Otter is used extensively in commuter airline service, and the SD 3-30 is being introduced for this purpose. The Marines are evaluating the Arava, and at least one air cargo carrier (Federal Express) is considering the Aviocar.

One additional aircraft was proposed for evaluation by the Division of Polar Programs: The Saab-Scania Transporter. Interest in this aircraft was engendered by an article in the May 24, 1976 Aviation Week, which showed a scale model of the aircraft. This scale model had been displayed at the Hanover Air Show. This is currently a concept, and neither a detailed design nor a production decision has been made. As this aircraft is merely a concept which would not be ready when the Division of Polar Programs wants to buy, it was not considered further.

With the exception of the SD 3-30, none of the candidate aircraft is new. The dates of first flight range from January 1963 for the Skyvan to August 1974 for the SD 3-30. Consequently, these aircraft were designed around engines (the PT-6A for the Twin Otter and the Arava, and the AiResearch TPE 331 for the Skyvan and the Aviocar) whose power is twenty to thirty percent less than certain more recent versions of the basic engines. The manufacturers of each of the candidate aircraft were asked whether or not they had any plans for upgrading the performance of their aircraft by retrofitting a more powerful version of the same engine. None of the manufacturers has plans to install a more powerful engine.

DeHavilland considers the only advantage of such a modification (unless it were accompanied by a major airframe modification) would be high altitude, hot day performance, and this advantage would not justify a significant change. Furthermore, DeHavilland considers the DHC-7, which is powered by four PT-6A's and is much too large for this application, to be the logical successor to the Twin Otter. Short considers that it has provided this upgrading by offering the SD 3-30 (which is powered by uprated PT-6A's), although this is a completely new airframe which has little configurational similarity with the Skyvan. I.A.I. has no intention of changing the engines in the Arava, and C.A.S.A. has not answered the question.

Performance, configuration, and cost information has been obtained from each of the manufacturers. These data have been modified so that they can be presented on a uniform and consistent basis.

The evaluation is divided into four separate sections: Performance Comparison, Features Comparison, Cost Comparison, and Users' Comments. The recommendations based on these comparisons and comments are presented in Table 9 on page 40.

PERFORMANCE COMPARISON

The candidate aircraft are evaluated on the basis of three basic performance requirements:

- Range-payload relationships
- Ferry range
- Single engine cruise capability

Although these aircraft are designed to achieve good short-field take-off performance, this feature was not used in the evaluation, as it is not critical in Antarctic operations.

The question arises, in making the performance calculations, as to what is the appropriate take-off gross weight. The Skyvan, the Arava, and the Aviocar have been certified, by the appropriate British, Israeli, and Spanish authorities, for operation at gross weights which exceed the 12,500 pound limit imposed by the FAA's FAR 23 or CAR 3 certification requirements. As the foreign certification gross weights (referred to as performance limits) are physically attainable, all calculations are made with both sets of weights. It is assumed that a weight which exceeds the certification limit could be used in an emergency, or on a rare occasion such as ferrying.

	Certification Limit T.O.G.W.	Performance Limit T.O.G.W.
Twin Otter	12,500	12,500
Skyvan	12,500	13,700
Arava	12,500	15,000
Aviocar	12,500	13,889
SD 3-30	22,000	22,000

RANGE-PAYLOAD RELATIONSHIPS

The range-payload relationships for each of the candidate aircraft are plotted in Figures 1 through 5. For the Skyvan, the Arava, and the Aviocar,

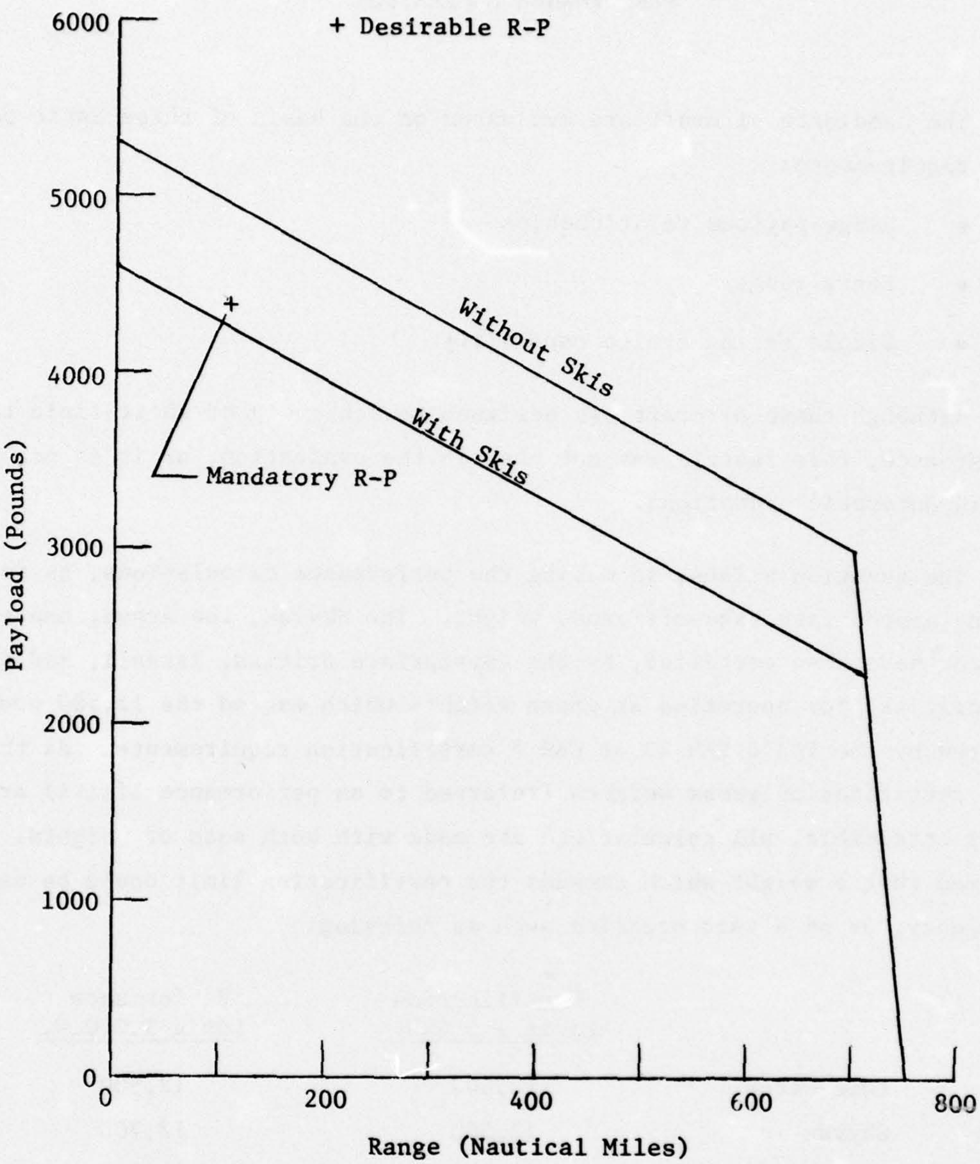


FIGURE 1. DeHAVILLAND DHC-6 TWIN OTTER RANGE-PAYLOAD RELATIONSHIP

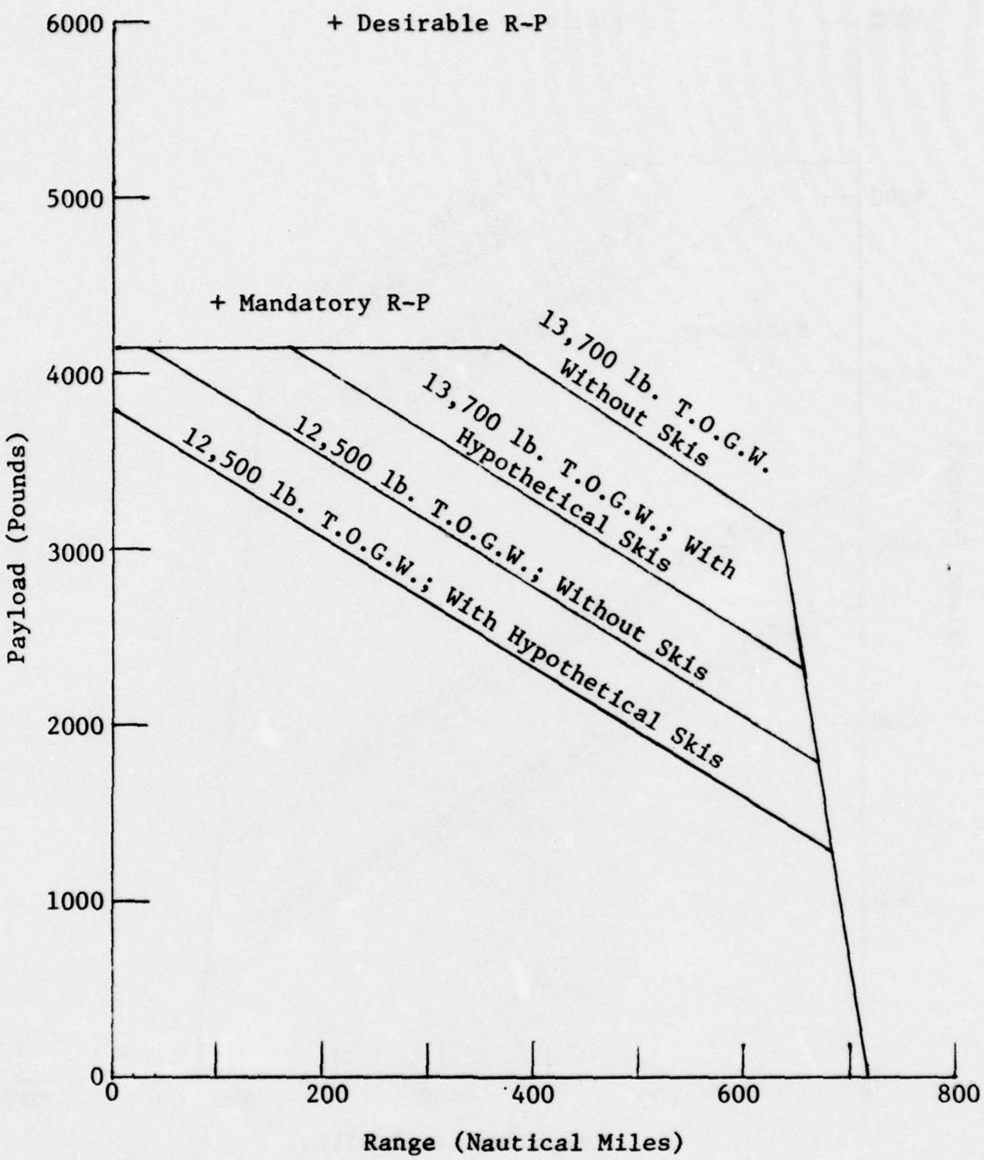


FIGURE 2. SHORT SC-7 SKYVAN
RANGE-PAYLOAD RELATIONSHIP

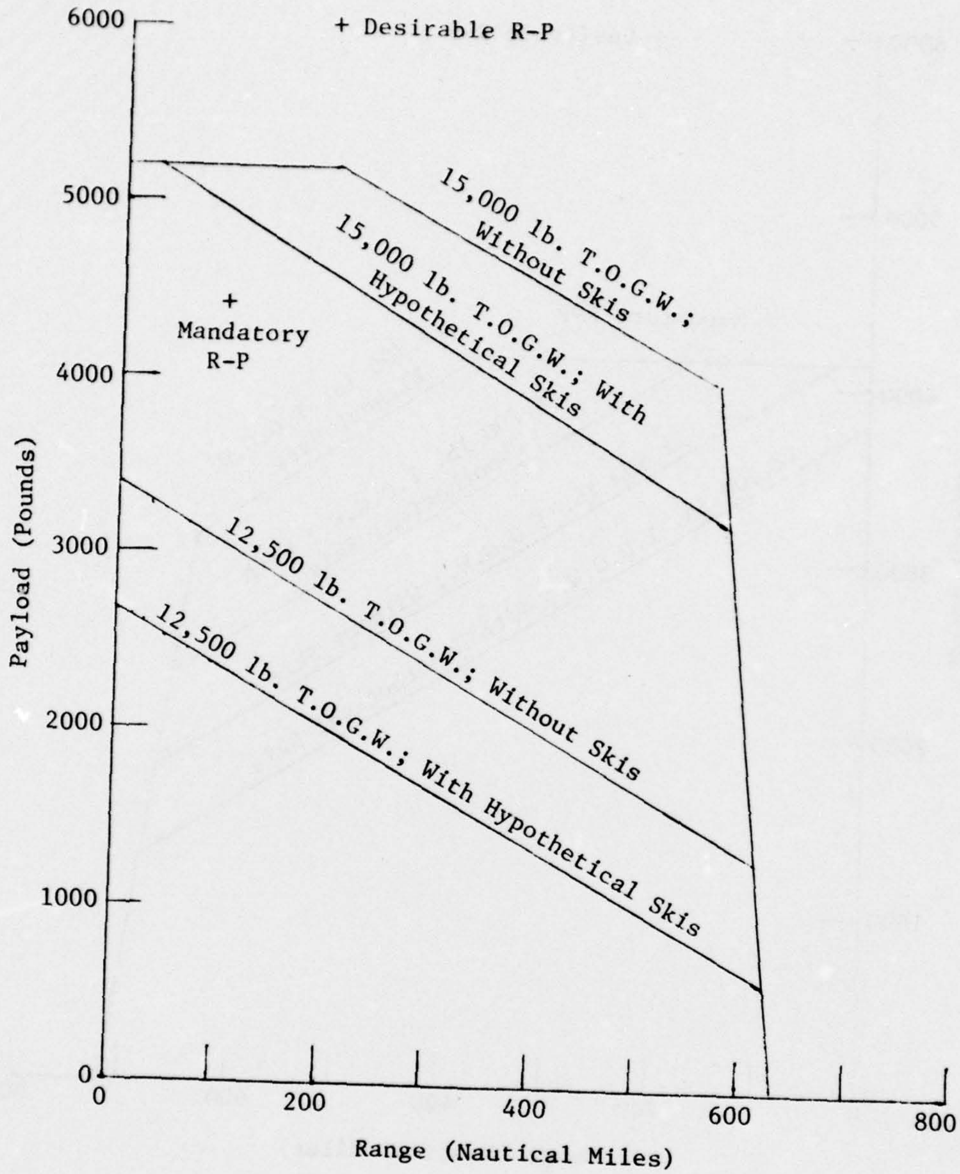


FIGURE 3. A.I.A. 100 ARAVA
RANGE-PAYLOAD RELATIONSHIP

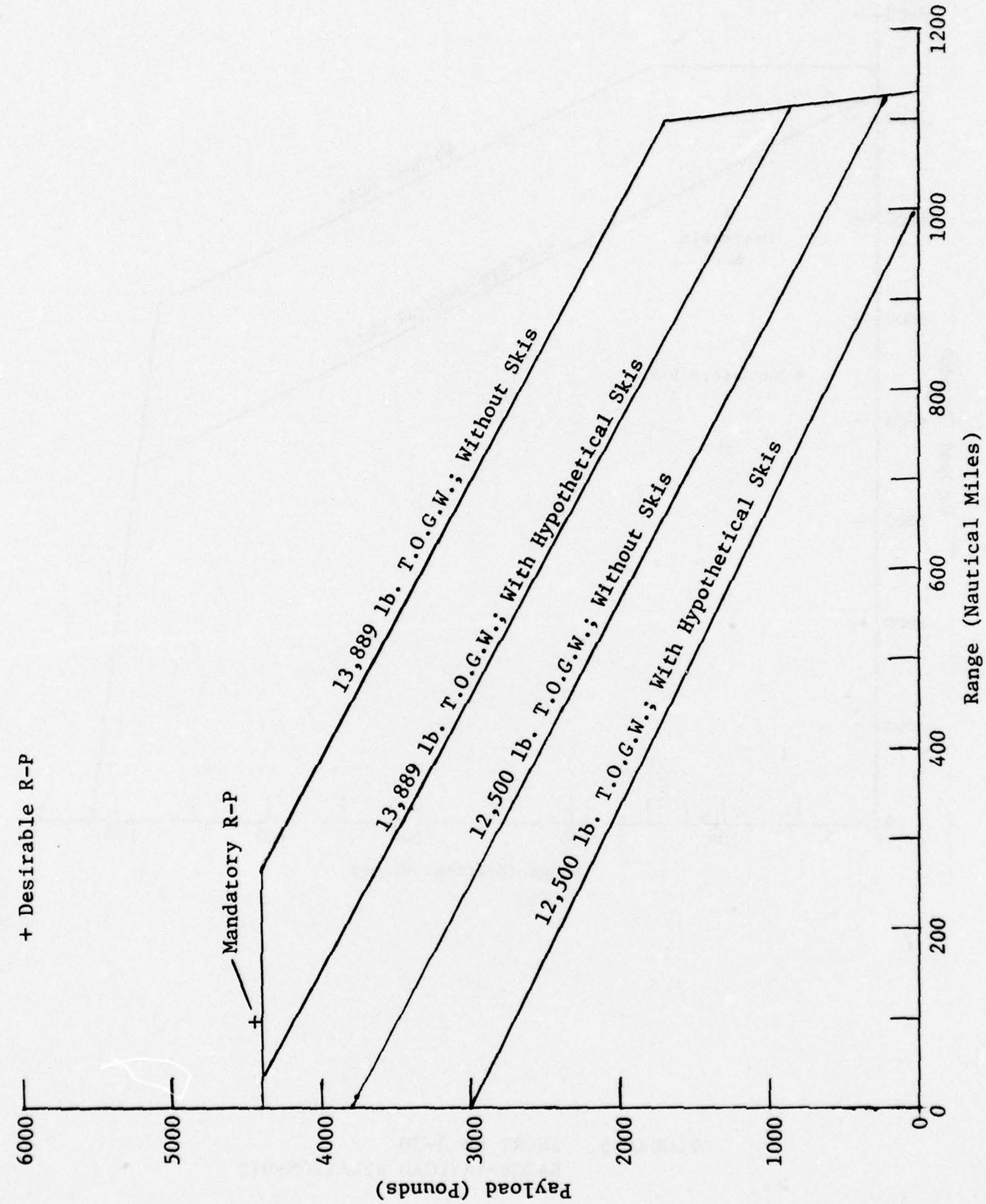


FIGURE 4. C.A.S.A. C-212 AVIOCAR
RANGE-PAYLOAD RELATIONSHIP

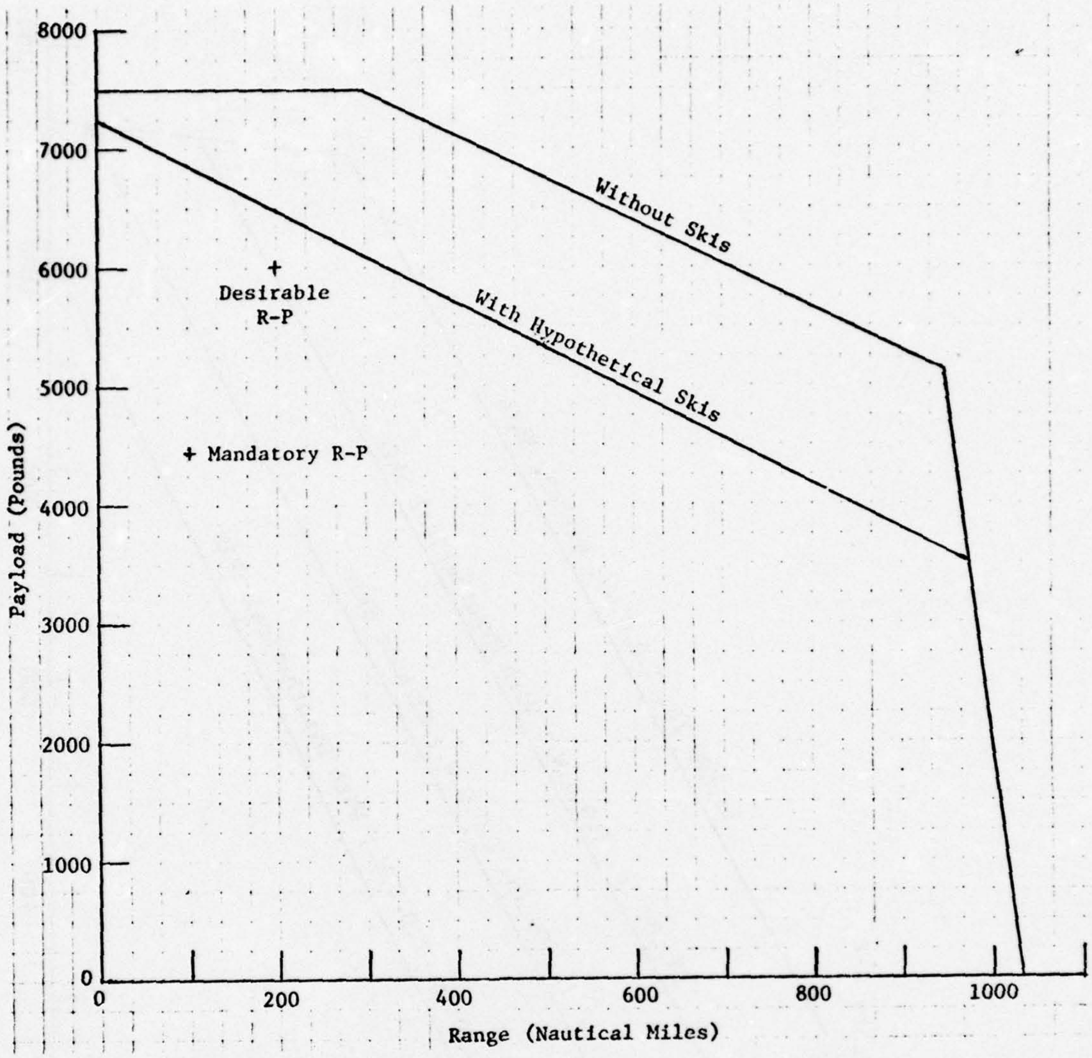


FIGURE 5. SHORT SD 3-30
RANGE-PAYLOAD RELATIONSHIP

curves are given for performance with a certification gross weight limit of 12,500 pounds, and for a take-off gross weight limited by performance. For the Twin Otter (which is the only one of the candidate aircraft with an operational ski landing gear), the range-payload relationship is shown with and without skis. This relationship for the other aircraft was estimated by subtracting 700 pounds of payload from the Skyvan, the Arava, and the Aviocar, and 1500 pounds of payload from the SD 3-30.

A composite set of range-payload curves is presented in Figure 6. These curves are based on operation at the certification limited take-off gross weight, and operation with a ski landing gear (which is actual with the Twin Otter, and hypothetical, but not necessarily unfeasible, with the other candidate aircraft). (Ski provisions and operations are discussed on page 25).

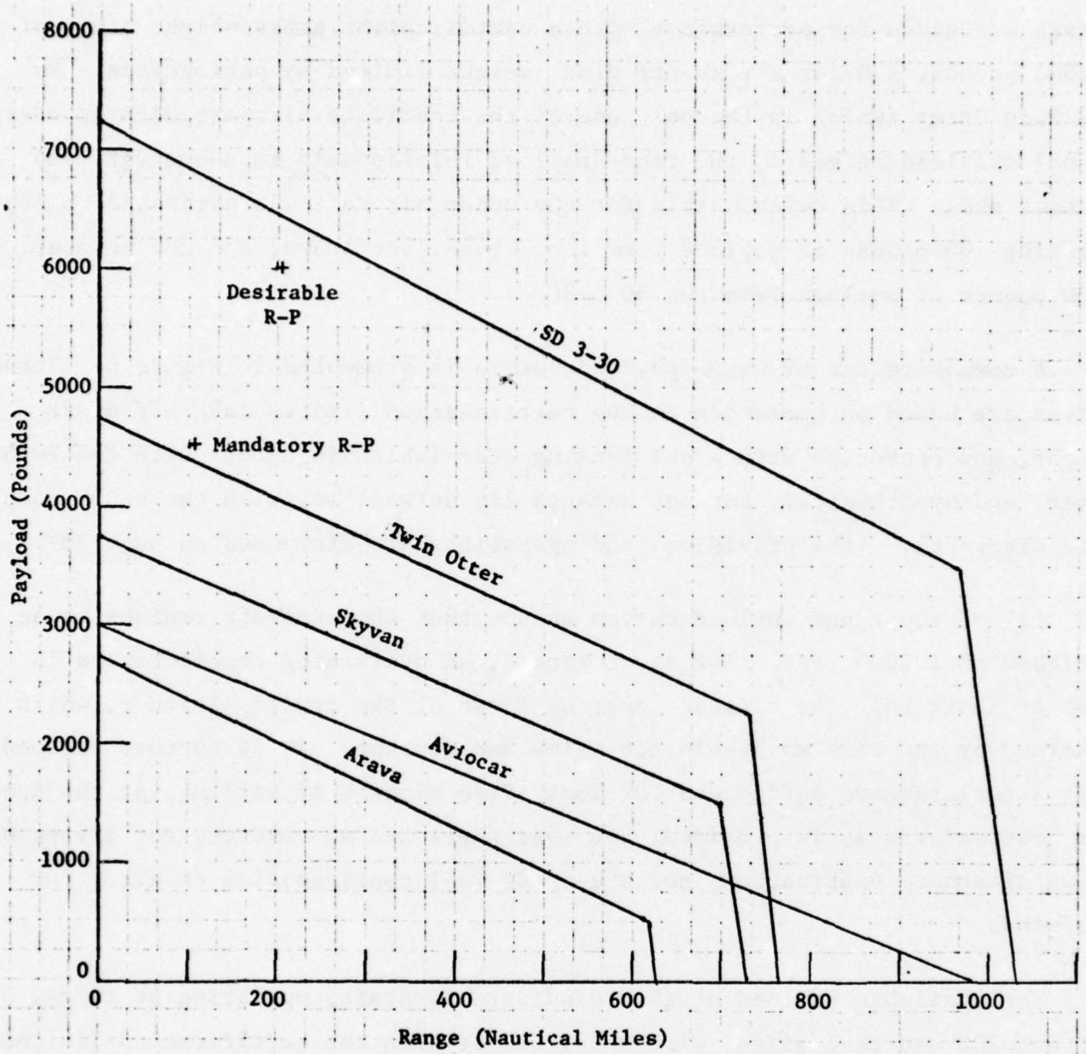
All of the range payload curves assume that the aircraft cruises at an altitude of 10,000 feet. For short ranges, an overriding consideration is that at least half the distance must be flown at the cruise altitude, which is governed by the time available for climb and descent. It is further assumed that a fuel reserve sufficient for forty-five minutes of holding, at the speed for best endurance, is provided, but that there are no reserves for diversion to an alternate destination, nor are there fuel contingencies to allow for headwinds.

The available payload of each candidate aircraft, operating at ranges of 100 and 200 nautical miles, with skis, and at both the certification-limited take-off gross weight and the performance-limited take-off gross weight, are presented in Table 3.

The significant conclusions which can be made, on the basis of these range-payload data, are:

1. The SD 3-30 is the only candidate aircraft which can achieve the the desired capability of carrying a 6000 pound payload for a range of 200 nautical miles.

2. The Twin Otter is the only other candidate aircraft which comes reasonably close (4250 pounds) to the mandatory payload requirement of 4400 pounds at a range of 100 nautical miles. (This 150-pound difference is less than the error which could be caused by the



Data represents performance at FAA-certified T.O.G.W. and with skis (hypothetical for all but Twin Otter).

FIGURE 6. RANGE-PAYLOAD COMPARISON

TABLE 3. PAYLOAD CAPABILITY AT SHORT RANGES

	T.O.G.W.	Payload at 100 n.mi. Range		Payload at 200 n.mi. Range	
		Without Skis	With Skis	Without Skis	With Skis
Specifications:					
Desirable	-	-	-	-	6,000
Mandatory	-	-	4,400	-	-
Certification Limit:					
Twin Otter	12,500	4,900	4,250√	4,650	4,000
Skyvan	12,500	3,750	3,050	3,450	2,750
Arava	12,500	3,000	2,300	2,650	1,950
Aviocar	12,500	3,400	2,700	3,050	2,350
SD 3-30	22,000	7,500	6,800√√	7,500	6,400√√
Performance Limit:					
Twin Otter	12,500	4,900	4,250√	4,650	4,000
Skyvan	13,700	4,150	4,150√	4,150	3,950
Arava	15,000	5,150	4,800√	5,150	4,450
Aviocar	13,889	4,400	4,200√	4,400	3,850
SD 3-30	22,000	7,500	6,800√√	7,500	6,400√√

√ Meets mandatory requirements.
√√ Meets desired requirements.

cumulative effect of the various assumptions.) As there is no significant difference between a 4250-pound capability and a 4400-pound payload requirement, the Twin Otter is assumed to meet the mandatory requirements.

3. The Arava can meet, and Aviocar and Skyvan can approach, the mandatory range-payload requirements only if they are operated at a gross weight which, although within the performance limits, exceeds the certification limits.

FERRY RANGE

The ferry ranges of the candidate aircraft are presented in Table 4. Values are presented for the maximum range with integral fuel tanks, and for the maximum range with auxiliary fuel tanks. For the Twin Otter, an auxiliary fuel system developed by the manufacturer, which consists of a set of several fifty-five gallon drums, supported by wooden racks, is used. For the other aircraft, auxiliary pillow tanks are assumed. In either case, it assumed that the weight of the auxiliary tanks is five percent of the weight available for auxiliary tanks and fuel.

In addition to the main integral tanks, the Twin Otter has optional integral wing tanks, which add another ninety-two gallons (600 pounds) of fuel, which is sufficient to increase its range from 760 to 960 nautical miles. The latter figure is sufficiently close to the desired requirement of 1000 miles to qualify the Twin Otter as meeting this requirement. Similarly, the Skyvan has supplementary integral tanks, mounted between the frames inside the cabin, to hold an additional 800 pounds of fuel. This increases the Skyvan's range with integral fuel from 725 to 985 nautical miles.

The ferry range calculations are based on a cruise altitude not to exceed 10,000 feet, for calculations involving integral fuel only. For the longer ferry missions, where auxiliary fuel systems are used, it is assumed that the cruise altitude is 25,000 feet. In all cases, sufficient reserve fuel for forty-five minutes holding, at the speed for maximum endurance, is assumed. No reserve fuel is allowed for diversion to alternate destinations, nor is any provision made for overcoming headwinds.

TABLE 4. FERRY RANGE CAPABILITY

Aircraft	T.O.G.W.	Ferry Range[1] with Main Integral Tanks (n.mi.)	Ferry Range[1] with Supplementary Integral Tanks (n.mi.)	Ferry Range[2] with Auxiliary Tanks (n.mi.)
Twin Otter	12,500	760✓	960✓✓	2406✓✓
Skyvan	12,500	725✓	985✓✓	1844✓
Skyvan	13,700	725✓	985✓✓	2270✓✓
Arava	12,500	630	-	1247✓
Arava	15,000	630	-	2009✓
Aviocar	12,500	1140✓✓	-	1339✓
Aviocar	13,889	1140✓✓	-	1745✓
SD 3-30	22,000	1025✓✓	-	2947✓✓

[1] No-wind range at 10,000' cruise altitude.
[2] No-wind range at 25,000' cruise altitude.

✓ Meets mandatory requirements.
✓✓ Meets desired requirements.

An examination of the data of Table 4 shows that the Twin Otter, the Skyvan, the Aviocar and the SD 3-30 can meet the desired integral fuel range requirements. The Arava, with its fuel supply limited to 2350 pounds, cannot meet either the desired or the mandatory range requirements, regardless of the take-off gross weight.

If auxiliary tanks are used, the Twin Otter and the SD 3-30 exceed the desired ferry range. The Skyvan can do so only if it is overloaded, although, at the certified take-off gross weight, the Skyvan, the Arava, and the Aviocar can easily exceed the mandatory ferry range.

The data to support the development of the ferry range, with auxiliary tanks, is presented in Table 5.

All the candidate aircraft have been ferried across the Atlantic (via Newfoundland, Greenland, and Iceland). Representatives of DeHavilland and Shorts have stated that this is a common practice, although the aircraft are usually overloaded at take-off.

SINGLE ENGINE PERFORMANCE

Single engine cruise capability (defined as the ability to maintain a fifty foot per minute rate of climb) is required at altitudes of 10,000 feet. It is desired that this be accomplished at a temperature of I.S.A. +0°C. (which is equivalent to a temperature of -5°C., or +23°F. at 10,000 feet altitude), with no reduction in payload. Furthermore, it is mandatory that this be accomplished at a temperature of I.S.A. -10°C. (which is equivalent to a temperature of -15°C., or +5°F. at 10,000 feet altitude), with at least eighty percent of its payload.

The Twin Otter, the Arava, the Aviocar and the SD 3-30 were able to cruise on a single engine at 10,000 feet, at a temperature of I.S.A. +0°C., at full certified gross weight, and consequently meet the desired, as well as the mandatory, specifications. The Skyvan was able to meet the mandatory specification, but under the conditions necessary to satisfy the desirable specifications,

TABLE 5. DEVELOPMENT OF RANGE AVAILABLE WITH AUXILIARY FUEL

Aircraft	T.O.G.W.	Integ. Fuel	ΔWt.[1]	Aux.[2] Cruise Fuel	Total Cruise Fuel	Avg. G.W.	SFC[3] (n.mi./lb)	Range (n.mi.)
Twin Otter	12,500	2457	3043	2651	5108	9,946	.471	2406
Skyvan	12,500	2300	2150	1743	4043	10,479	.456	1844
Skyvan	13,700	2300	3350	2883	5183	11,109	.438	2270
Arava	12,500	2350	1350	983	3333	10,834	.374	1247
Arava	15,000	2350	3850	3358	5708	12,146	.352	2009
Aviocar	12,500	3700	50	0	3450	10,775	.388	1339
Aviocar	13,889	3700	1439	1082	4782	11,498	.365	1745
SD 3-30	22,000	3840	5260	4627	8467	17,767	.348	2947

[1] Useful load, less integral fuel.

[2] Ninety-five percent of ΔWt., less allowance for 45 minutes holding at maximum endurance speed.

[3] Estimated Specific Fuel Consumption average at 25,000 feet altitude.

the gross weight was limited to 12,200 pounds. This would require a three hundred pound, or approximately ten percent, off-loading of payload.

The results of these calculations are presented on Table 6.

SUMMARY PERFORMANCE COMPARISON

The capability of each of the candidate aircraft to meet the four basic performance specifications (range-payload capability, range with integral tanks, ferry range with auxiliary tanks, and single engine cruise capability at 10,000 feet altitude) is presented in Table 7.

The principal conclusions from these data are:

1. The SD 3-30 is the only one of the candidate aircraft which meets or exceeds the desired performance requirements in all categories.

2. The Twin Otter is the only other aircraft which meets or exceeds the mandatory performance requirements in all categories, without being over-loaded beyond its certified maximum take-off gross weight. Furthermore, in all performance categories other than range-payload the Twin Otter meets or exceeds the desired, as well as the mandatory requirements.

3. None of the aircraft with rear loading (Skyvan, Arava, and Aviocar) meets all of the desired performance requirements.

TABLE 6. SINGLE ENGINE CRUISE CAPABILITY AT 10,000 FEET ALTITUDE

Aircraft	Max GW @ 10,000 Ft.		% of Full Payload		Temperature at Which Off-loading Required
	I.S.A.[1] - 10°C	I.S.A. + 0°C	I.S.A. - 10°C	I.S.A. + 0°C	
Twin Otter	12,500+	12,500+	100	100√√	I.S.A. + 18°C (+ 13°C)
Skyvan	12,500+	12,200	100√	90	I.S.A. - 4°C (- 9°C)
Arava	14,000	13,200	100	100√√	I.S.A. + 15°C (+ 10°C)
Aviocar	12,500+	12,500+	100	100√√	I.S.A. + 12°C (+ 7°C)
SD 3-30	22,000+	22,000	100	100√√	I.S.A. + 0°C (- 5°C)

[1] International Standard Altitude.

√ Meets mandatory requirements.
√√ Meets desired requirements.

TABLE 7. SUMMARY PERFORMANCE COMPARISON

Aircraft	T.O.G.W.	Range-Payload	Ferry Range (integral tanks)	Ferry Range (auxiliary tanks)	One Engine Cruise (10,000ft)
Twin Otter	12,500	✓	✓✓	✓✓	✓✓
Skyvan	12,500	–	✓✓	✓	✓
Skyvan	13,700	✓	✓✓	✓✓	✓
Arava	12,500	–	–	✓	✓✓
Arava	15,000	✓	–	✓	✓✓
Aviocar	12,500	–	✓✓	✓	✓✓
Aviocar	13,889	✓	✓✓	✓	✓✓
SD 3-30	22,000	✓✓	✓✓	✓✓	✓✓

✓ Meets mandatory requirements.
✓✓ Meets desired requirements.
– Does not meet requirements.

FEATURES COMPARISON

BASIC SIMILARITIES

Each of the five candidate aircraft has certain features which make it appropriate for use in primitive conditions in Antarctica. Foremost among these are two configuration requirements: a high-wing, and twin-turbine propulsion.

All these aircraft have engines which are rugged, in common use, and which have been proved over several years of operation. The Twin Otter, the Arava, and the SD 3-30 use different versions of the Canadian Pratt & Whitney PT-6A. The Skyvan and the Aviocar use different versions of the Garrett AiResearch TPE 331.

The Skyvan, the Arava, and the Aviocar were developed primarily as military aircraft, for missions such as cargo and troop transport, paratroop drop, and medevac. They were designed for rugged field operations. As such, they have been adapted for a variety of commercial support operations.

The Twin Otter was developed for commercial and military passenger and light cargo carriage. Although it does not have the simplified cargo-handling features of the other three aircraft, it has been adapted for cargo, utility, and field support operations.

The SD 3-30 has been designed as a short-haul commercial passenger aircraft. The manufacturer is considering offering a cargo version.

SKI OPERATIONS

Each of the five candidate aircraft was evaluated on the basis of its suitability for ski operations, which is a mandatory requirement.

Of these five aircraft, the Twin Otter is the only one in which a ski landing gear is offered by the manufacturer, and which has a proven record of successful ski operations. It has been used not only by the American but also

by the British, Chilean and Argentine Antarctic expeditions. It is extensively used in Canada, Alaska and Greenland and is used by both the Norwegian and Canadian Armed Forces.

The Skyvan does not have a proven ski landing gear. A prototype ski was developed and had limited testing for the Series 1 Skyvan. This version of the aircraft is no longer in production. The skis designed for the Series 1 Skyvan cannot be used on the current (Series 3) version because of differences in the landing gear. For example, the Series 1 nose gear had twin wheels whereas the Series 3 has a single nose wheel.

Shorts had considered developing a ski-wheel landing gear but decided not to do so as the market was rather limited and the Twin Otter had effectively pre-empted this market. Shorts estimates that it could sell fewer than ten additional aircraft if it offered a ski gear and decided that the incremental revenue from these sales would not justify the development of such a gear. Shorts would require that any prospective purchaser who wanted a ski gear would assume the considerable development cost involved. (The British Antarctic expedition selected the Twin Otter instead of a British aircraft because of the availability of a proven ski installation for the Twin Otter.)

Neither the Arava nor the Aviocar are offered with a ski gear, and the manufacturers have no plans for developing one.

The SD 3-30 has not been developed with a ski gear and it is unlikely that this would occur as the aircraft has a retractable landing gear and consequently modification for ski operation would be expensive and heavy. Such a development is not impossible, however, as the C-130, which also has a retractable gear, has had a ski installation successfully developed.

Although none of the aircraft other than the Twin Otter has a ski installation, a weight penalty for hypothetical skis was assumed. The Twin Otter's ski installation weighs 680 pounds, which is slightly more than five precent of the design take-off gross weight of 12,500 pounds. Consequently, a weight penalty of five percent of the certified design take-off gross weight was assumed for hypothetical ski gear for the Skyvan, the Arava, and Aviocar. As

these aircraft have fixed landing gear but have not gone through an appropriate ski development program, the assumption of the same weight penalty as the Twin Otter is conservative.

The weight penalty of a hypothetical ski for the SD 3-30 is likely to be a greater percentage of the gross weight than that of the other aircraft, principally because the SD 3-30 has a retractable landing gear. Consequently, it was assumed that the weight penalty for hypothetical ski gear for the SD 3-30 is seven percent of the gross weight or approximately 1500 pounds.

According to information received from DeHavilland of Canada, if the skis are trimmed properly, there is no measurable drag penalty. This statement was used as the basis of the assumption that none of the aircraft would incur a drag penalty if it were equipped with skis.

LOADING CONVENIENCE

The loading convenience of each of the candidate aircraft was investigated, as the lack of such a convenience is the principal detriment to the Twin Otter currently in use.

The Twin Otter has a side-opening door which is fifty-two inches above the surface and heavy, cumbersome items such as fifty-five gallon drums of fuel oil or mechanized toboggans must frequently be loaded and unloaded. Manual loading through the side door is cumbersome, and requires much effort. Consequently, the candidate aircraft were examined to see what improvements would be available.

The Skyvan, the Arava and the Aviocar were designed for convenient loading and unloading cargo. Each of the aircraft features a rear cargo door the full width of the cabin which is hinged at the bottom and can be used as a loading ramp. Furthermore, the Arava has the capability of enabling one to completely remove the cargo door and attach a fairing for transporting cargo which would not fit in the cabin.

Unfortunately, the three aircraft with the most convenient loading arrangements are the three with the poorest performance. Therefore, the feasibility of modifying the Twin Otter and the SD 3-30 was investigated. All of the following comments apply to the Twin Otter as preliminary indications tend to show that this aircraft is far better suited for the proposed application than the SD 3-30.

In analyzing the loading of the Twin Otter and investigating ways in which it might be improved, the approaches which were considered were those which would either reduce the effort required to load heavy items or provide for the loading of a large item, such as a mechanized toboggan.

An analysis was made of the maximum dimensions of an object which could be loaded through the Twin Otter's cargo door. Although the doorway is fifty-six inches wide, the cabin is only fifty-two inches wide at its widest point. Furthermore, the cabin is tapered in the vicinity of the door. This makes it necessary to load long items at an angle. The limits to the length and width of flat rectangular items which can be loaded through this door are shown in Figure 7. Supplementary data in Table 8 indicate the length, width, and the angle between the transverse and the center-line of the item being loaded. The dimensional data indicate that the clearances for loading a mechanized toboggan on to the Twin Otter are quite close.

DeHavilland was asked whether or not it would be feasible to increase the width of the cargo door. The answer was negative, because it would involve a major structural rework with significant weight penalties.

Two possible approaches were considered for reducing the load effort: a retractable boom and a portable ramp.

A retractable boom would be mounted on certain reinforced longerons so that the angle between the boom and the fore-and-aft axis of the aircraft could be varied (varying from being ninety degrees to the door for loading drums to approximately forty-five degrees for toboggans). Such a boom would be manually retractable and could be fitted with a differential hoist. The weights and moment arms involved do not affect the ground stability of the aircraft.

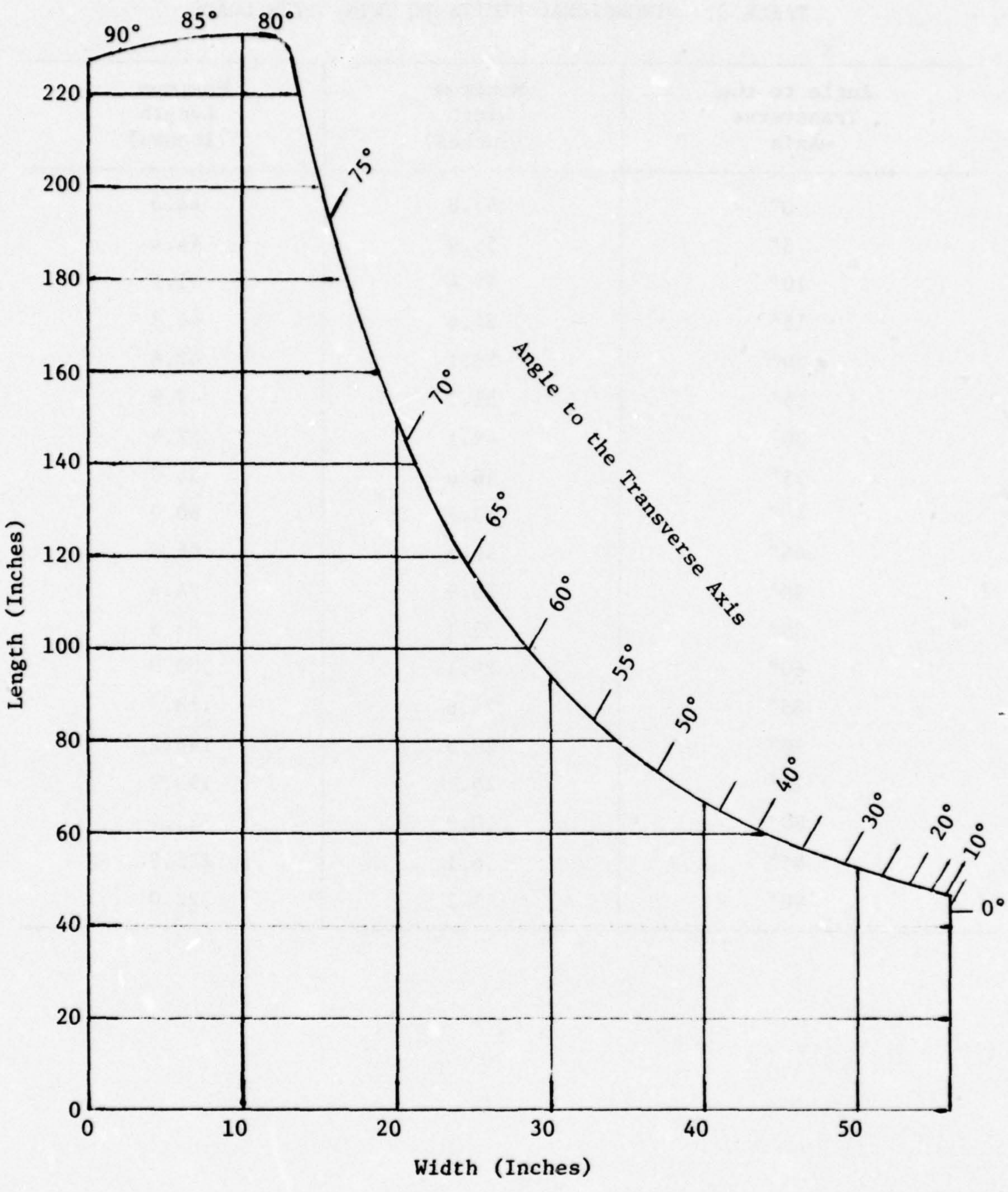


FIGURE 7. DeHAVILLAND TWIN OTTER LENGTH-WIDTH LIMITS FOR CARGO LOADING

TABLE 8. DIMENSIONAL LIMITS TO TWIN OTTER LOADS

Angle to the Transverse Axis	Maximum Width (inches)	Maximum Length (inches)
0°	55.8	44.0
5°	55.9	44.4
10°	55.4	45.1
15°	54.4	46.3
20°	53.1	47.8
25°	51.3	49.9
30°	49.1	52.5
35°	46.6	56.0
40°	43.7	60.3
45°	40.5	66.0
50°	36.9	74.6
55°	33.1	83.5
60°	29.1	100.0
65°	24.8	118.3
70°	20.3	146.2
75°	15.7	193.2
80°	10.9	223.4
85°	6.1	222.8
90°	1.2	222.0

DeHavilland felt that this concept would not be feasible as considerable structural rework would be required unless it were possible to mount the boom directly on the frames. Such a mounting would reduce the capability of adjusting the boom to different angles.

The other concept involves a set of rollers fitted within channels which would be supported on ball and socket fittings attached to the frame in the vicinity of the sill. The mountings would permit these roller-planks to be set at different angles to the aircraft to accept different sizes of cargo. It is envisioned that a winch would be used to achieve a reasonable mechanical advantage. This would require several different inboard attachment fixtures.

An initial investigation of the roller-plank concept shows that the most feasible arrangement would involve twin roller planks, approximately twelve feet long, supported on a pair of ball-and-socket joints outside the aircraft, just below the cargo door sill. This would result in the roller planks being at an angle of approximately twenty degrees to the ground, on a level surface. The roller planks could easily be stored in the cabin.

A winch with a mechanical advantage of four to one* is recommended. A parbuckle arrangement for drums would double this advantage. As the slope of the roller planks is one to three, the overall mechanical advantage is twelve to one (and twenty-four to one for the drums). Consequently, the heaviest of loads could be pulled aboard with an effort of less than forty pounds.

Sketches of the roller plank concept, and associated fittings and gear, are presented in Figures 8 and 9. It is conservatively estimated that this system would weigh not more than 110 pounds.

Several manufacturers of aircraft cargo loading systems were contacted, and the feasibility of this concept, and the manufacturers' ability and willingness to fabricate it, were determined. A list of manufacturers is presented in Appendix C.

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*Common, relatively light and inexpensive sailboat and boat trailer winches develop at least this advantage.

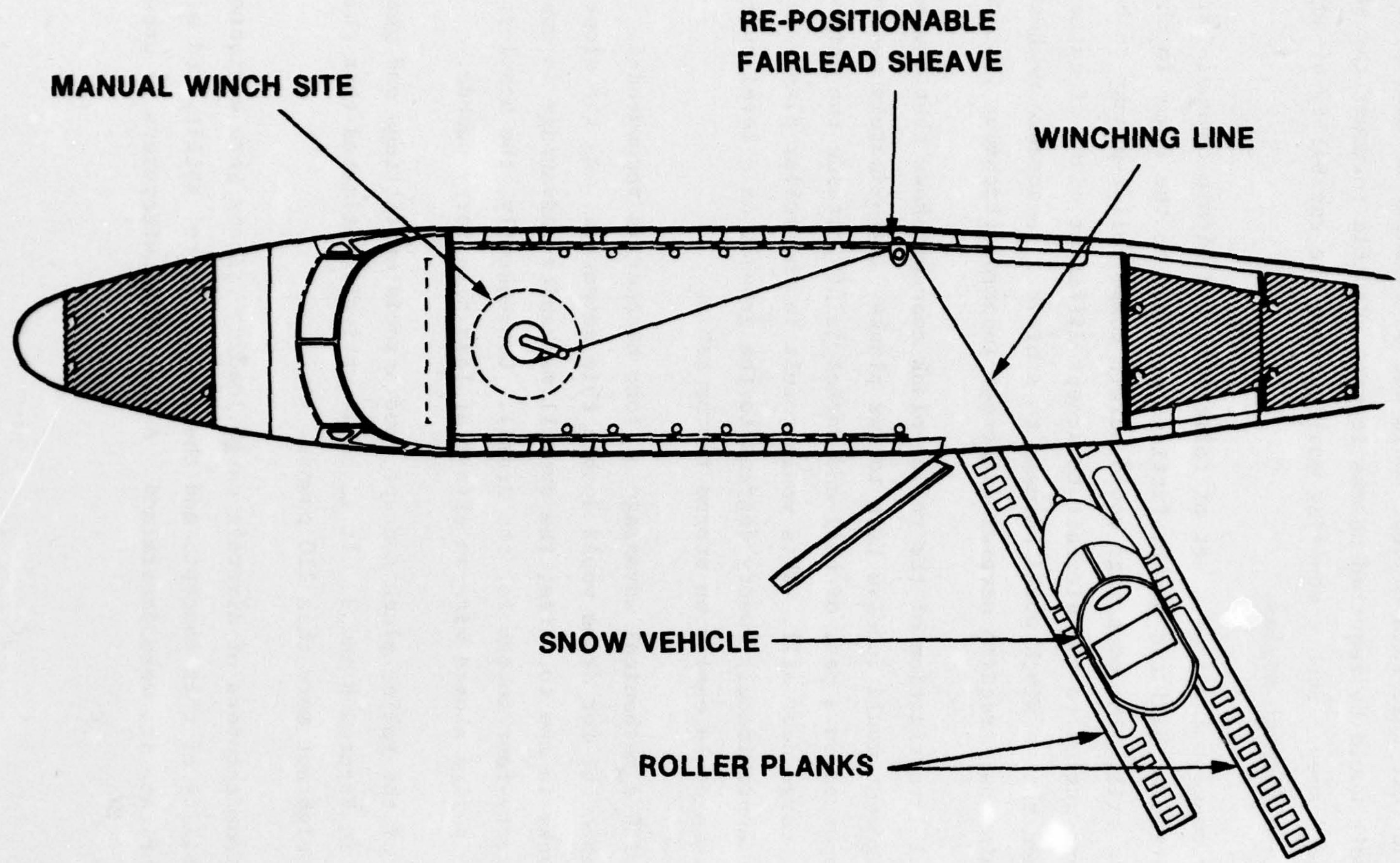

FIGURE 8. PLAN VIEW OF SNOW VEHICLE BEING WINCHED ABOARD TWIN OTTER ON ARTICULATED ROLLER PLANKS

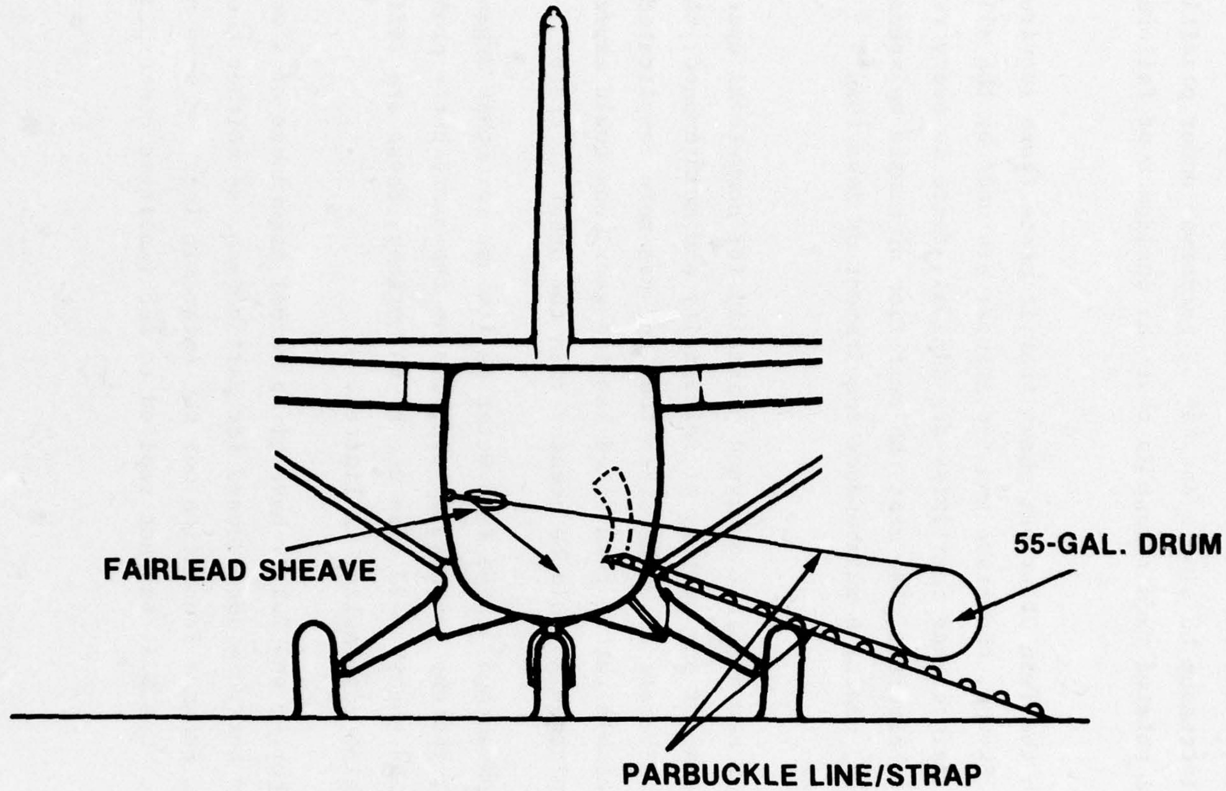

FIGURE 9. SECTION VIEW OF DRUM BEING WINCHED AND PARBUCKLED ABOARD TWIN OTTER ON ROLLER PLANKS

FIELD MAINTENANCE

A paramount requirement for the aircraft selected by the Division of Polar Programs is that maintenance be simple and can be performed under primitive field conditions. A related requirement is that the incidence of failure be low.

Experience with the Twin Otter has shown that it meets these requirements. Furthermore, as the Skyvan, the Arava and the Aviocar are used by the military in situations where maintenance facilities are minimal, there is every reason to believe that these aircraft also meet the criterion of simple maintenance. The Arava for example, claims a maintenance requirement of less than 0.5 man-hour per flight hour.

The SD 3-30 is a new aircraft designed primarily for commercial operation. Although it is too new for any history of reliability and maintenance, the fact that it is a larger aircraft than the other four and has more complicated systems (such as retractable rather than fixed landing gear) one could expect that its maintenance requirements would be greater than the other aircraft.

A significant advantage of the Twin Otter is its use for other organizations in Antarctica, thereby potentially simplifying the spare parts problem. Although the Arava and the SD 3-30 also use PT-6A engines, these are different versions and the engine commonality is limited.

DeHavilland, Shorts, and I.A.I. have given verbal assurances of a world-wide support program but were not pressed for particulars, as neither the identity of the National Science Foundation nor the Antarctic location were revealed to any manufacturer. C.A.S.A. has not replied to our inquiries concerning support services.

COST COMPARISON

With regard to a choice among candidates, acquisition cost is the most significant cost factor for these aircraft. Flight and maintenance crew costs would be virtually the same for any candidate, as would fuel and other consumables--except in the case of the SD 3-30. The provision for spare parts and the use of maintenance materials can reasonably be considered as a percentage of the procurement cost.

The following current prices were quoted by the aircraft manufacturers:

Twin Otter	$ 655,000*	(no avionics)
Skyvan	$ 678,000	(no avionics)
Arava	$ 875,000	(with avionics)**
Aviocar	No quote given	
SD 3-30	$1,250,000	(fully equipped commercial)
	$1,100,000	(estimated utility version no avionics)

*Canadian dollars.
**Price without avionics not available.

USERS' COMMENTS

If the recommended aircraft had been an aircraft other than the Twin Otter, a number of users would have been contacted, to solicit their subjective opinions of the aircraft. As the Twin Otter is the recommended aircraft, and as the Office of Polar Programs is familiar with this aircraft, such an effort was not necessary.

The armed forces of three different countries (Argentina, Ecuador, and Indonesia) operate more than one aircraft type of the set of candidate aircraft. The Air Attaches of these countries were contacted, in an effort to determine the reasons for selecting different aircraft. The conclusion reached was that there was no criterion of choice used that would be significant to the Division of Polar Programs.

The U.S. Army has recently initiated procurement of two off-the-shelf Twin Otters on behalf of the Alaska National Guard. Delivery has not yet been made; thus no usage experience has been gained in that application.

RECOMMENDATIONS

The analysis of the ability of each of the five candidate aircraft to meet the performance and features requirements shows that none of the aircraft can meet all of the desired requirements. Consequently, the selection decision needs to be based on the aircraft which comes closest to meeting the most important criteria.

Although five aircraft are considered, three of them (the Skyvan, the Arava and the Aviocar) can be considered as a single group, for they are similar in their ability to satisfy the specified requirements.

Considering the Twin Otter, "the group," and the SD 3-30, each tends to have one overriding advantage. The Twin Otter's unique advantage is its proven ski operation. The Skyvan, the Arava and the Aviocar have straight-in cargo loading capability. The SD 3-30 is the only aircraft which meets all of the performance requirements.

The ability of each of the aircraft to meet the various requirements is tabulated in Table 9. It is significant that the Twin Otter is the only aircraft capable of meeting all of the mandatory requirements.

The principal disadvantages of the Twin Otter are that, while it can meet the mandatory, it can not meet all the desired, performance requirements; and it does not have a straight-in cargo loading feature. However, the disadvantages of the other aircraft are more serious. The Skyvan, the Arava and the Aviocar can not meet even the mandatory performance requirements if they are operated at the certified take-off gross weight. Furthermore, they do not have a proven ski landing gear. These failures to meet mandatory requirements are much more serious than the Twin Otter's lack of straight-in cargo landing.

When the Twin Otter is compared with the SD 3-30, the latter does have superior performance, although the Twin Otter meets the mandatory standards. The SD 3-30, however, does not have a ski landing gear, and maintenance is likely to be more complicated than that of the Twin Otter.

TABLE 9. AGGREGATE AIRCRAFT COMPARISON

	Twin Otter	Skyvan	Arava	Aviocar	SD 3-30
Mandatory Requirements:					
4400# payload @ 100 n.mi.	✓	–	–	–	✓
700 n.mi. ferry {integral tanks}	✓	✓	–	✓	✓
1000 n.mi. ferry {auxiliary tanks}	✓	✓	✓	✓	✓
Single engine cruise (10,000', ISA - 10°C, 80 percent full payload)	✓	✓	✓	✓	✓
Twin turbines	✓	✓	✓	✓	✓
High wing	✓	✓	✓	✓	✓
Ski landing gear	✓	–	–	–	–
Simple maintenance	✓	✓	✓	✓	?
Desirable Requirements:					
6000# payload @ 200 n.mi.	–	–	–	–	✓
1000 n.mi. ferry {integral tanks}	✓	✓	–	✓	✓
2200 n.mi. ferry {auxiliary tanks}	✓	–	–	–	✓
Single engine cruise (10,000', ISA, full payload)	✓	–	✓	✓	✓
Straight-in loading	–	✓	✓	✓	–
Commonality	✓	–	–	–	–

Considering all of these factors, we recommend that the Division of Polar Programs procure the Twin Otter. This recommendation is reinforced by the successful experience which has been gained already with the operation of this aircraft in the Antarctic. A corollary recommendation is that a portable, stowable, lightweight set of rollers, mounted in twin channels, together with a winch, be used to reduce the effort of loading and unloading.

APPENDIX A

AIRCRAFT USERS

DeHAVILLAND DHC-6 TWIN OTTER

Orders have been received for 510 Twin Otters, as of June 1, 1976. Jane's All the World's Aircraft (1976) states that 452 aircraft had been sold by January 1, 1975. Most of these aircraft are being used for commercial purposes.

Following is a partial list of military users.

Argentine Air Force	6
Argentine Army	2
Canadian Armed Forces	8
Chilean Air Force	11
Ecuadorian Air Force	3
Jamaican Defense Force	1
Royal Norwegian Air Force	4
Panamanian Air Force	1
Paraguan Air Force	1
Peruvian Air Force	12
Uganda Police Air Wing	1
	50

SHORT SC-7 SKYVAN

The Skyvan has been built in three different versions, of which the current, Series 3 (and its military version, 3M) is the most numerous. Jane's All the World's Aircraft (1976) lists ninety-five orders received, as of April 1, 1975. The forty-eight civil customers were not identified; the military customers are listed below:

Argentine Naval Prefectura	5
Austrian Air Force	2
Eduadorian Army Air Force	1
Ghanan Air Force	6
Indonesian Air Force	3
Royal Nepalese Army	2
No. 2 Squadron of the Sultan of Oman's Air Force	16
Singapore Air Defense Command	6
Royal Thai Police	3
Yemen Arab Republic Air Force	2
Undisclosed	1
	47

I.A.I. - 101 ARAVA; I.A.I. - 201 MILITARY ARAVA

At least twenty-seven military Aravas, and an undisclosed number of civilian ones, had been produced by May 31, 1975, Jane's All the World's Aircraft, 1976 edition. As I.A.I.'s current production rate is three per month, and orders have been received for production through March 1977, it is reasonable to assume that total orders represent more than ninety aircraft.

The users of the twenty-seven military aircraft are:

Bolivian Air Force	6
Ecuadorian Army and Air Force	10
Israeli Air Force	3+
Mexican Air Force	5
Nicaraguan Air Force	1
Salvadorean Air Force	2
	27+

C.A.S.A. C-212 AVIOCAR

Orders have been received for ninety-two military versions of the C-212, according to the 1976 edition of Jane's All the World's Aircraft. There are no known civilian users.

The military users are:

Indonesian Air Force	6
Jordanian Air Force	4
Portugese Air Force	28
Spanish Air Force	42
Venezuelan Air Force	12
	92

Additionally, the Mexican Air Force has ordered a number of C-212's during the past year.

APPENDIX B

CERTIFICATION STATUS

FULLY CERTIFIED

- DeHavilland DHC-6 (Twin Otter)

  CAR 3, and FAR 23, Part 135 Operation.

  12,500 lb. max., T.O.G.W.

  Type certificate A9EA.

  Fully certified for ski operations.

- I.A.I. 101 (Arava)

  FAR 23.

  12,500 lb. max. T.O.G.W.

  Type certificate A32EU.

- Short SC-7, Series 2 and 3 (Skyvan)

  CAR 3.

  12,500 lb. max. T.O.G.W.

  Type certificate A15 EU.

  Also certified under British Civil Air-Worthiness Requirements, Passenger Transport Category, Performance Group A, for operation at a maximum T.O.G.W. of 13,700 pounds.

CERTIFICATION BEING PROCESSED

- Short SD 3-30

  FAR 25 certification expected June 1976.

  22,000 lb. max. T.O.G.W.

  Currently certified under British Civil Air-Worthiness Requirements, Passenger Transport Category, for operation at a maximum T.O.G.W. of 22,000 pounds. Type Certificate BA 11.

- C.A.S.A. C-212 (Aviocar)

  FAR 23 certification process begun May 1976.

  Could take several months to complete.

  Currently certified to joint military and civil standards by the Instituta Nacional de Technica Aerospacial.

APPENDIX C

INFORMATION SOURCES

AIRCRAFT MANUFACTURERS:

Construcciones Aeronauticas, S.A. (C.A.S.A.)

Rey Francisco, 4; Apartado 193
Madrid (8), Spain
Dr. Fernando de Caralt, Director of Marketing
Mr. Pablo de Bergia, Regional Sales Director, North America

The DeHavilland Aircraft of Canada, Ltd.

Garratt Boulevard
Downsview, Ontario M3K 1Y5
(416) 633-7310
Mr. John F.B. Shaw, Director, Western Hemisphere Sales
Mr. L.L. ("Slim") Jones, Manager, North American Sales

Short Brothers & Harlan, Ltd. (Shorts Aircraft)

U.S. Liaison Office
Third Floor, Tower Building
Logan International Airport
Boston, Massachusetts 02128
(617) 569-6110
Mr. Maurice J. Averay, Manager Technical Sales
Mr. T.O. Dennison

Israel Aircraft Industries (I.A.I.)

505 Park Avenue
New York, N.Y. 10022
(212) 486-5909
Mr. Fred Mendes

Commodore Aviation, Inc. (I.A.I.'s U.S. marketing subsidiary)

505 Park Avenue
New York, N.Y. 10022
(212) 486-5909
(703) 323-5227
Mr. Marvin G. Klemow, Director of Marketing Services, North America

CERTIFICATION:

Federal Aviation Administration

Engineering and Manufacturing Division
Flight Standards Service
800 Independence Avenue, S.W.
Washington, D.C. 20591
Mr. James E. Purcell, Chief (202) 426-8160
Mr. Waterman, Deputy Chief (202) 426-8374

MANUFACTURERS OF CARGO HANDLING EQUIPMENT:

Brooks & Perkins, Inc.

12633 Inkster Road
Livonia, Michigan
(313) 522-2000
Mr. Bud Lefebvre (X216, 217)

Brownline Division, Brooks & Perkins

2950 Lomita Boulevard
Torrance, California 90505
(213) 539-0320
Mr. George Cleland

Brownline East (East Coast marketing organization)

126 Albany Avenue
Freeport, I.I., N.Y. 11521
(516) 546-2202
Mr. Edward A. Scharback

(The Brownline Division of Brooks & Perkins has designed and/or manufactured the cargo systems for the C-130, C-141, C-5A, CH-53A, and L-1011.)

Ground Support Engineering

1301 S.W. 70th Avenue
Miami, Florida 33144
(305) 264-4350
Messrs. Syx and Logan

(Ground Support Engineering designs and fabricates loading ramps and platforms, maintenance platforms, etc.)

Cochran Equipment Company

Cochran-Webster Corporation
1215 Hansen Street
Salinas, California 93901
(408) 758-4461
Mr. Barton

(Cochran manufactures aircraft and industrial cargo handling systems, but discourages small orders.)

Food Machinery Corporation

Colmar, Pennsylvania
(215) 822-0581
Mr. Horace Swartz, Manager of Materials Handling

(Food Machinery Corp. designs and manufactures industrial materials handling systems. Although this firm expressed a willingness to submit a bid, it felt that the design effort required would make it so expensive that the bid would be rejected.)

Wollard Aircraft Service Equipment, Inc.

6950 N.W. 77th Avenue
Miami, Florida 33148
(305) 592-5450

(Wollard designs and manufactures aircraft cargo handling systems, although it is best known for its passenger jet-ways. It discourages small orders.)